national accelerator laboratory

EXP-36
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ACCELERATOR EXPERIMENT--Acceleration in Other Diamonds in the Main Ring

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Date and Duration: 17 March 1973, 2000 to 2245 hours
23 March 1973, 1400 to 1600 hours

I. Introduction

For a variety of reasons, a brief exploration of main-ring beam behavior at tunes significantly different from those associated with the normal operating region is of interest. The last time that this sort of thing was done was during the period 21-23 December 1971 (see EXP-3), at which time coasting beam was more easily maintained in the region $20.5<\nu_x,\nu_y<21.0$ than in the design operating region. Orbit-position information was not available then, and the circumstance that the design operating region was opened up by the use of trim dipole corrections on the 20th harmonic suggests we simply had a larger 20th than 21st harmonic in that field component. Nevertheless, similar differences may exist in the harmonic content of the higher order fields. A motivation of a different sort arises from the long-term goal of acceleration to the 500-GeV energy range; quality deterioration of the quadrupole fields due to saturation can be avoided by adopting a low tune--say 16.25--as the operating point.

These measurements were intended to precede a more detailed examination of the design diamond, $20.0<\nu_x,\nu_y<20.5$; however, scheduling considerations made it desirable to defer the latter part of the work, so only the "other" diamond exploration is reported here.

II. Description of the Experiment

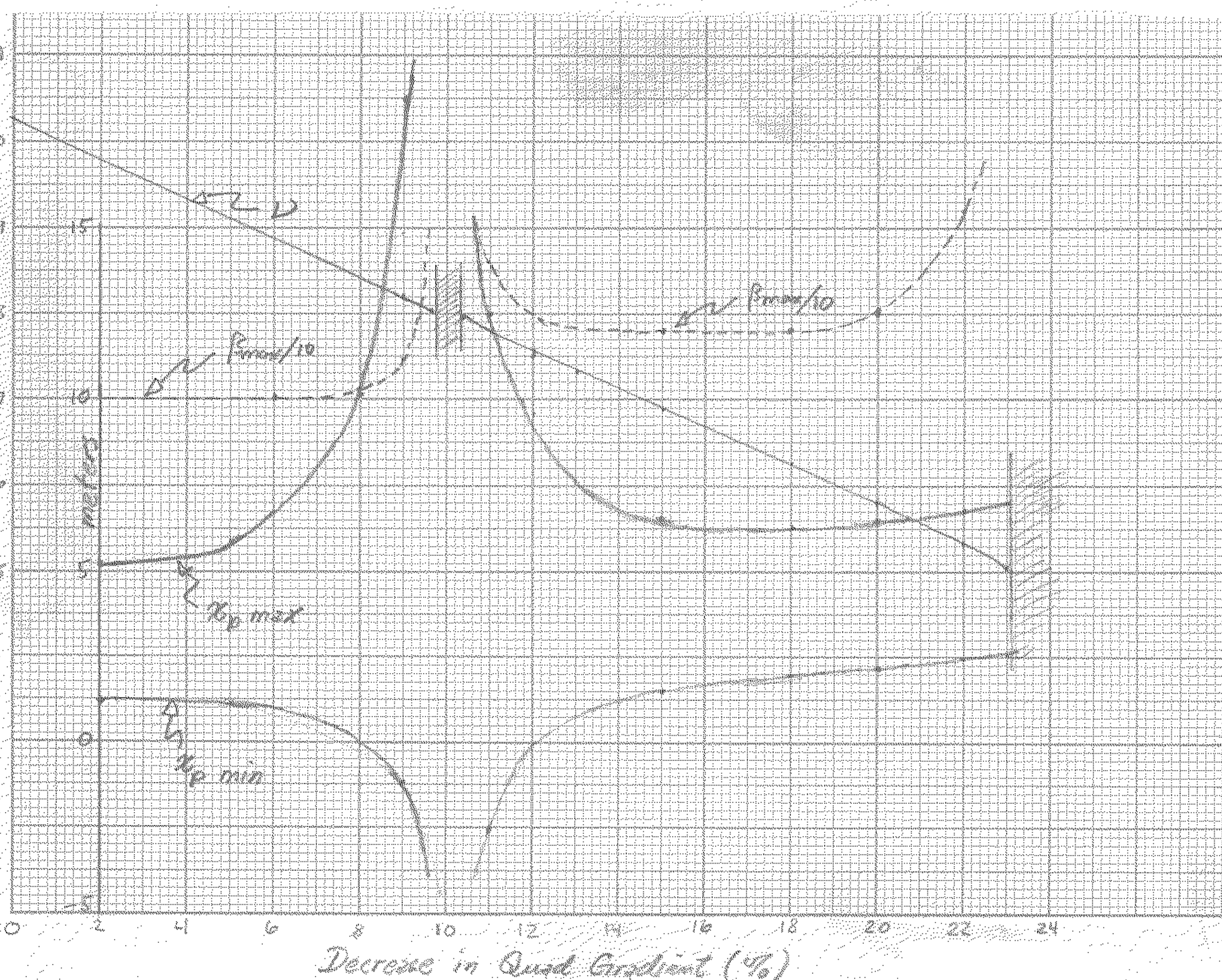
The work on 17 March began by setting up a 100-GeV ramp with a 3.6-sec cycle, a step that was taken in order to speed up the taking of data over the remainder of the 8-hour period scheduled for this investigation. In retrospect, it may have been better to stay with the existing 300-GeV ramp, for a ground fault, associated with a shorted bending magnet, terminated the exercise at 2245, reinforcing the evidence that at least some magnet failures are precipitated by thermal cycling.

However, prior to the ground fault, operation at $\nu \sim 20.75$ had been established and the qualitative differences of December 1971 were no longer to be observed; overall main-ring transmission and the time distribution of beam loss were not obviously different from the state of affairs at the design tunes.

On 23 March, the operating point was lowered to $\nu \sim 19.25$ and $\nu \sim 16.25$. For small variations in the operating point from the design value, the linear approximation is adequate; the tune shifts in terms of parameters which are displayed in the control room may be written:

$$\begin{aligned} \delta\nu_x &= 0.0633\ \Delta R_F + 0.1217\ I_s \\ \delta\nu_y &= 0.0633\ \Delta R_F - 0.3744\ I_s \end{aligned} \qquad (1)$$

Here, ΔR_F is the difference in readings (in millivolts) of the transductor on the F-quad bus, and I_s is the split current (amps)--I_s is positive when the F-bus current is higher than that in the D-bus. The splitter was not used in the work reported here. For the large change in tune involved in dropping to a 16.25 operating point, it is advisable to resort to a more detailed calculation. In December 1969, when the question of attaining 500 GeV with the main-ring quads arose, I calculated the dependence of certain parameters on diminution of the quad current; the results are summarized in the graph following. In this calculation, neither dipole nor quadrupole errors were introduced, so the only stopbands shown arise from long straight section mismatch, at $\nu = 15$ and $\nu = 18$. The region near $\nu = 18$ shows the expected distortions in the displaced equilibrium orbit parameters. At $\nu = 16.25$ β_{max} and the dispersion functions are, of course, larger than at $\nu = 20.25$ but not distressingly so. Radial and vertical tunes and amplitude functions are not distinguished in this plot since only fringe focusing differentiates the two planes. Just prior to the experiments, SYNCH runs were made by



W. W. Lee to provide a more detailed picture of the variation of the several important parameters with tune at selected point, including $\nu = 16.25$ on the tune versus quad strength curve.

At the normal operating point, initial readings of the bend and quad transductors were 386.4 mV and 371.6 mV, respectively. A radial tune of 19.25 was obtained by lowering the quad reading to 356 mV, just as predicted by Eq. (1). Beam was readily accelerated to 300 GeV after adjustment of the time of transition jump to compensate for the lowering of transition energy. Measurements of closed orbits at various times in the cycle revealed only modest differences in the orbit distortions at this lower tune. After a few minutes tuning on injection, the main-ring transmission was in the 30% to 35% region.

The quad current was next lowered to a transductor reading of 304.6 mV; an 18% reduction from that at the normal operating point. An additional 2 mV reduction was necessary to bring the fractional part of the tune to 1/4, probably reflecting the influence of remanent gradients in the quadrupoles. The establishment of a coasting beam required use of harmonic corrections in the trim dipoles. Closed orbit plots were then possible, revealing distortions at injection energy consuming about half the aperture both radially and vertically. Acceleration through the parabola was obtained by introduction of a quad bump and a shift in the time of the transition phase jump. As expected, the beam could not be carried to above 100 GeV or so; modification in the quadrupole regulation system would have been required to go higher. Orbit plots near the peak energy achieved indicated aperture utilization similar to that observed at injection. The accelerated beam intensity was about one-third that at higher tunes; a lower intensity is not surprising though, since not only was little time spent on improving the beam, but the full resources for beam optimization developed for 20.25 (e.g., dipole bumps, automatic orbit correction) were not applicable here.

The experiment was terminated at 1600 hours on 23 March due to the reappearance of intermittent ground faults which had interrupted operation during the hour prior to the beginning of this work.

III. Conclusions

It seems to me that we can draw two (at least tentative) conclusions from the above observations. First, there is no dramatic improvement to be found in working in other diamonds; rather, we must develop our understanding of beam loss where we normally operate. Second, insofar as 500-GeV operation is concerned, a tune of 16.25 appears quite feasible, though an orbit correction process similar to that pursued throughout the past year will be necessary to exploit this possibility.

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